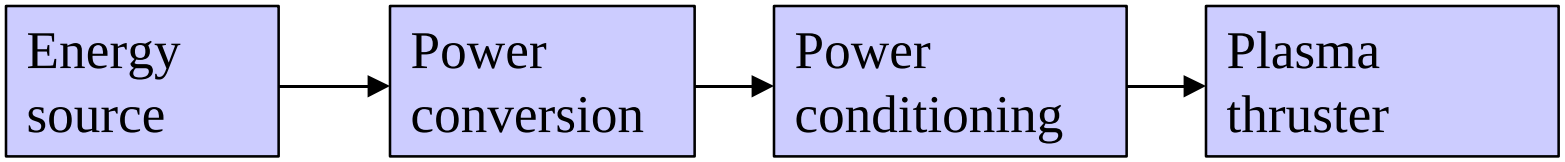
Types of Plasma Propulsion

- Two major types of plasma propulsion
- Type I: Indirect Drive

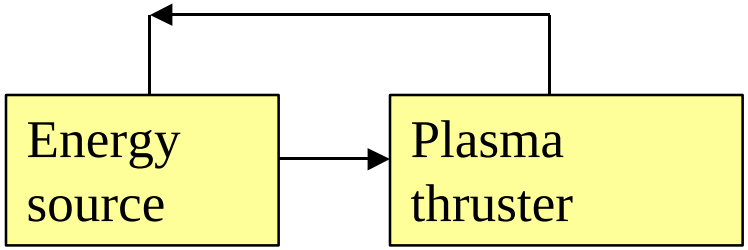


Solar
Nuclear fission

Solar voltaic
Electric generators

V-I transform
Switching
Pulse shaping

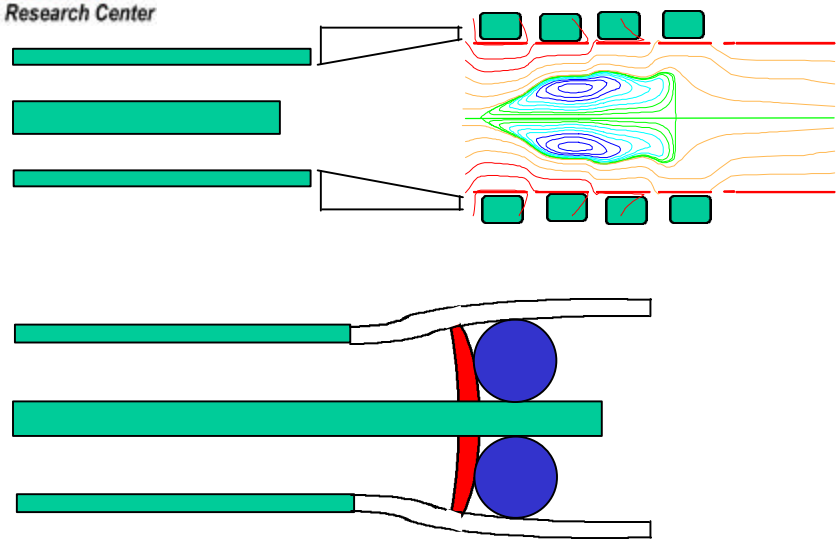
- Type II: Direct Drive



e.g. Fusion

Propulsion Research Center

Compact Toroid Plasma Thruster



- **Description**
  - The Compact Toroid Plasma Thruster is a high-power, high variable impulse, high efficiency, electromagnetic plasma thruster
  - Exploits the stability of self-organized plasma states (compact toroids) to produce long and efficient acceleration thus attaining high velocity and high kinetic energy
  - Uses the Lorentz force for accelerating the plasmoids in both the directly coupled mode and in the inductive mode

- **Application(s)**
  - Significant reduction in cost and trip time in planetary travel
  - Enhance fast robotic and human access to the planets: large cargo and human missions
  - Provide the needed high-power and high efficiency electric rocket for solar electric or nuclear electric propulsion
- **General benefit(s)**
  - High efficiency
  - Scalable to extremely high power (MW's)
  - High speeds (50-100 km/s) can be attained

Fusion Propulsion

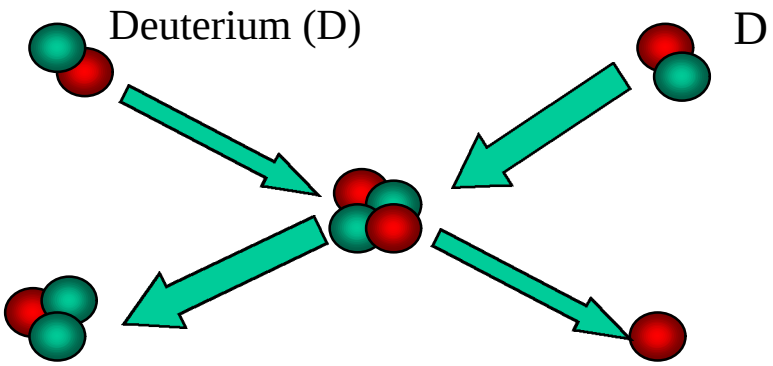
Propulsion Research Center

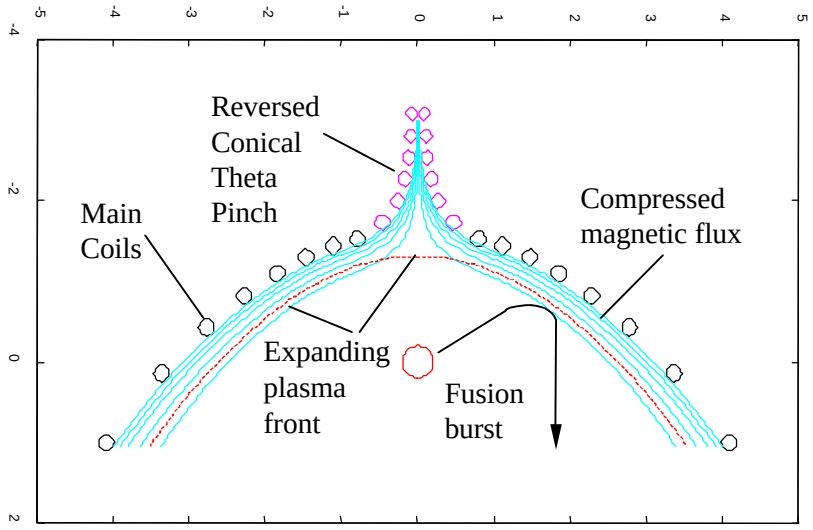
The fusing of atomic nuclei:

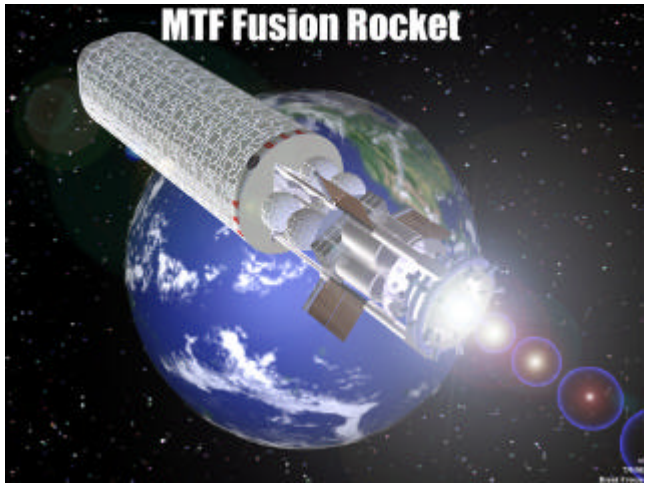
D + D → ^{3}He (0.82 MeV) + *n* (2.45 MeV)

D + D → T (1.01 MeV) + *p* (3.03 MeV)

D + T → ^{4}He (3.52 MeV) + *n* (14.06 MeV)







Fusion produces a high-temperature plasma, ideal for producing thrust directly, without the intermediate mass-intensive step of producing electricity

Jet power: 2 GW, Dry mass: 50 tons
Isp: 500 ~ 77,000 s
Thrust: 2.7 tons - 100 tons
Trip time to Mars: 1 month

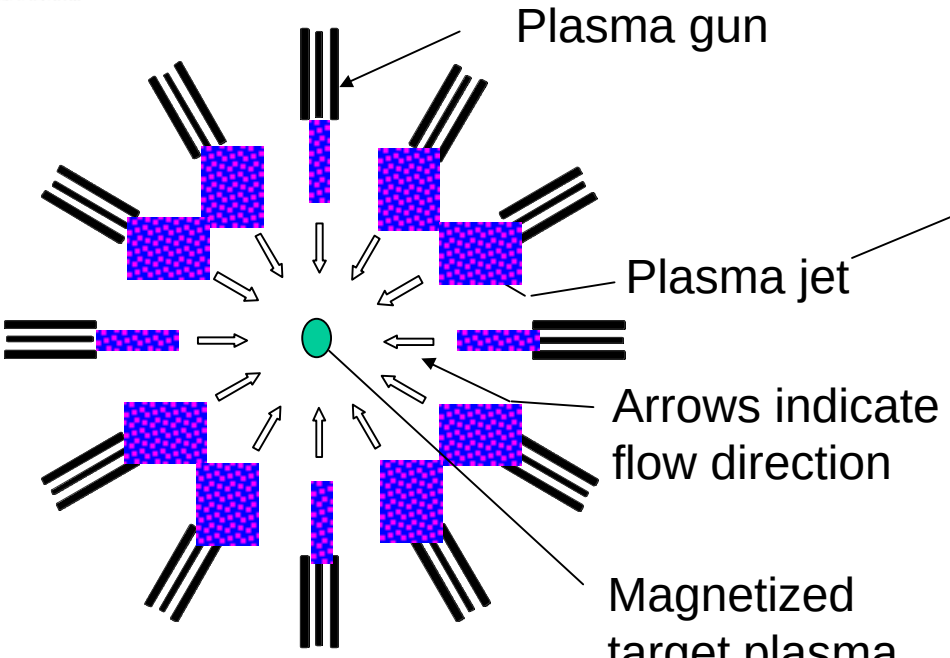
Propulsion Research Center

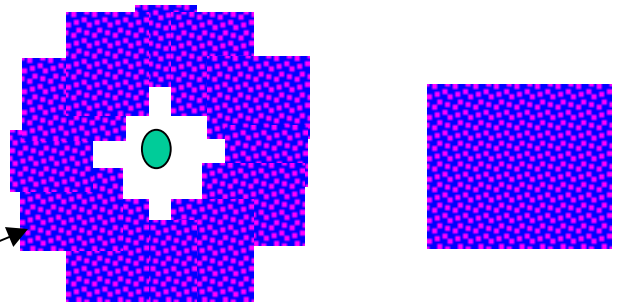
Differences between Fusion for Propulsion vs Terrestrial Electrical Generation

Propulsion	**Terrestrial Power Generation**
Conversion of fusion energy to **thrust**	Conversion of fusion energy to **electricity**
Mass per unit jet power	**Cost** per unit electrical energy
Open cycle	**Closed** cycle
Vacuum is a **natural** environment in space	Vacuum needs to be **generated**
NASA can use it **NOW**!	The need depends on: • Other energy supplies • Environmental concerns

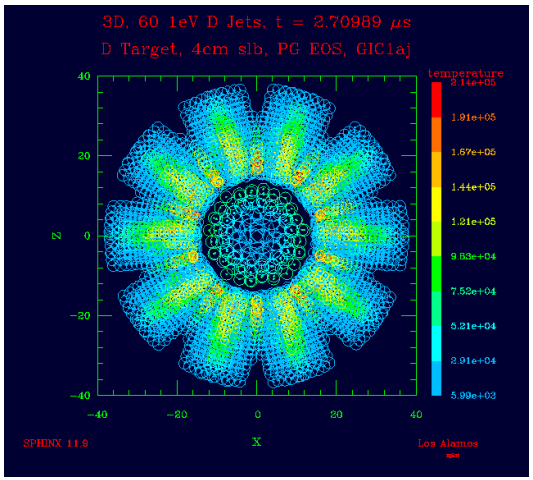
Magnetized Target Fusion

Propulsion Research Center





The jets merge to form a spheroidal shell (liner), imploding towards the center

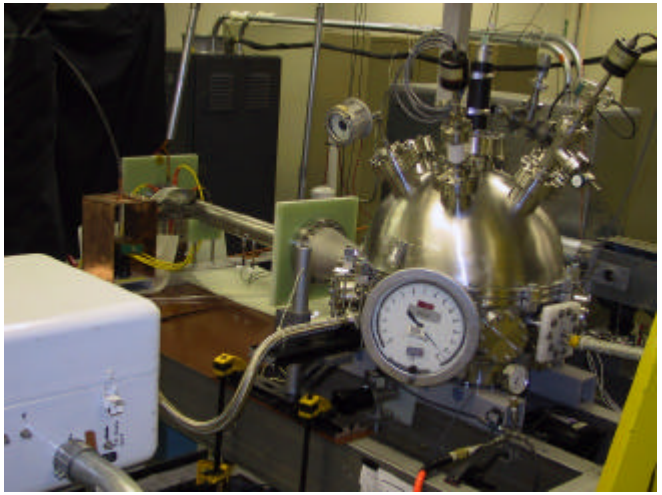


- An approximately spherical array of jets are fired towards the compact toroids (~ 200 km/s)

3-D hydrodynamics modeling results indicate plasma liner formation and compression of target plasma to fusion conditions

Magnetized Target Fusion with Plasma Liner

Propulsion Research Center



- Physics exploratory experiment underway
- Reproducible initiation of plasma in time ($\Delta t < 1\ \mu s$) and space ($\Delta z < 1$ cm) demonstrated in a high-power plasma thruster, with the use of 6 trigatrons
- Accelerated 0.2 mg of plasma to 50 km/s
  - Max. thrust of ~2000 N in a pulse of 10 μs
  - Isp ~ 5,100 s

- High-speed photographs of the plasma jet
- Taken with different shots with different time delays
- The jet moves from left to right
- The well-collimated nature of the jet is apparent